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Inventors: Cassondra L. Crotty, Daria R. Dooling, David E. Moran, Ralph J. Williams

For: METHOD FOR VISUALIZING DATA

Enclosed are:

☒ (9) sheets of drawing.

☒ An assignment of the invention to International Business Machines Corporation.

☒ A Declaration and Power of Attorney.

☐ A verified statement to establish small entity status under 37 CFR 1.9 and 37 CFR 1.2

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Indep Claims	12-3=	9	x $39	$	OR	x $78	$702
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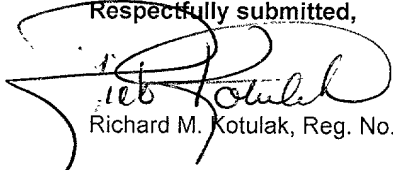   ☒ Any filing fees under 37 CFR 1.16 for presentation of extra claims.

INTERNATIONAL BUSINESS MACHINES CORPORATION
Intellectual Property Law - Mail 972E
1000 River Street
Essex Junction, VT 05452
(802) 769-4457
mf

Respectfully submitted,

Richard M. Kotulak, Reg. No. 27,712

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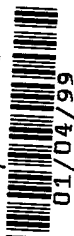
APPLICATION

FOR

UNITED STATES LETTERS PATENT

APPLICANT NAME: Cassondra L. Crotty, Daria R. Dooling,
David E. Moran, Ralph J. Williams

TITLE: METHOD FOR VISUALIZING DATA

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INTERNATIONAL BUSINESS MACHINES CORPORATION

METHOD FOR VISUALIZING DATA

TECHNICAL FIELD

The present invention relates generally to graphical computer systems and, more specifically, to a method and system for visualizing data.

BACKGROUND OF THE INVENTION

Scientific visualization involves displaying large sets of data generated in the process of investigating a scientific or engineering problem. In many engineering applications, large linear systems of equations arise. Such applications include, for example, simulation of nonlinear microwave circuits, robotic control, or power systems design. Linear systems of equations are typically expressed in the form

$$Ax = b, \qquad (1)$$

where $A \in R^{n \times n}$ or $A \in C^{n \times n}$, i.e., A is a square n-dimensional matrix with real or complex elements, $x \in R^{n \times 1}$ and $b \in R^{n \times 1}$, or $x \in C^{n \times 1}$ and $b \in C^{n \times 1}$, i.e., x and b are either real or complex n-dimensional vectors. The entries of the matrix A are values that arise from the physical system involved. For example, the matrix A is often a Jacobian matrix related to a nonlinear algebraic equation associated with a physical system, e.g., a conductance matrix of an electronic circuit, where x is a voltage vector and b is a current vector.

A matrices characterize both numerical and structural properties of the physical system. Numerical or quantitative properties are indicated by the elements of A

being, for example, "real," "complex," "positive," "negative," "integer," or "floating point" to name just a few. Structural or qualitative properties are related to the position or indexing of the elements of the matrix. The position of an element in a matrix is indexed by integers indicating the row and column position of the element. Note that matrices are 2-dimensional arrays and some physical systems may involve higher dimensional arrays such as 3-dimensional arrays. In the case of a 3-dimensional array, for example, the position of elements in the array are indexed by a row, a column, and a plane. Characterization of structural properties of a matrix include, for example: dense matrices, in which many of the elements of the matrix are non-zero; sparse matrices, in which many of the elements of the matrix are zero; Hermitian or symmetric matrices, in which a matrix equals its adjoint; and skew-symmetric matrices, in which the elements of the transpose of the matrix have the opposite sign from the elements of the matrix.

Many numerical methods exist for the solution of systems of equations expressed in the form of equation (1); see, for example, Kendall E. Atkinson, "An Introduction to Numerical Analysis," (Wiley, 1989), and Yousef Saad, "Iterative Methods for Sparse Linear Systems," (PWS Publishing Company, 1996). Numerical methods for the solution of these systems of equations include reordering, preconditioning, factoring, and substitution. The choice of numerical method for the solution of equation (1) is guided by the numerical and structural characteristics of the physical systems modeled.

There are conventional software packages that allow a user to store and display data arrays, such as

matrices. For example, commercial software packages such as MATLAB® by the Math Works Inc. or MATHEMATICA® by Wolfram Research. These software packages, however, may not be able to display a conductance matrix associated with the

5 operation of an electrical circuit with millions of components. The main difficulty with conventional packages is the limitation placed on allocation of memory provided for the storage of data arrays, thus limiting the ability of conventional packages to display large arrays. The

10 deficiencies of the conventional software packages show that a need still exists for a method and system which permit visualization of large sets of data.

SUMMARY OF THE INVENTION

The difficulty of choosing an appropriate and

15 efficient numerical method for the solution of the engineering problem may be overcome by graphical visualization of the data. In particular, it may be insightful to graphically view a matrix such as the A matrix of equation (1). For example, a microprocessor

20 integrated circuit (IC) may use four signal types: power signals, clock (timing) signals, control signals, and data signals. Each signal type is described by a reactive network having one or more resistive, capacitive, and inductive components. Such a network may contain 1-10

25 million components for each signal type. Each such network is described by an equation of the form $Ax = b$. In particular, the direct current (dc) solution of a microprocessor (IC) power signal network may be represented by an equation $Ax = b$, with A symmetric and positive

30 definite. In the case for which A is symmetric and positive definite, Cholesky factorization and backward substitution may be applied to solve the equation $Ax = b$.

To meet this and other needs, and in view of its purposes, the present invention provides a method and system for visualizing data arrays represented in the form of a plurality of data values. A grid is generated based on the plurality of data values. Each data value is associated with a geometric shape. The geometric shapes associated with the data values are placed on the grid. The visual and geometric information placed on the grid are reported to a user in graphical form.

In addition, it is possible to identify one of a plurality of numerical attributes associated with each data value of the plurality of data values, and associate with each numerical attribute one of a plurality of visual attributes. Then, each data value is associated with a geometric shape having one of the plurality of visual attributes. The geometric shapes associated with each data value of the plurality of data values are placed on the grid. The visual and geometric information placed on the grid are reported to a user in graphical form.

Alternatively, the present invention provides a method and system for visualizing data provided in the form of a geometric representation. A plurality of data values are extracted from the geometric representation. A graphic representation of the plurality of data values is generated. The graphic representation is displayed to a user.

It is to be understood that both the foregoing general description and the following detailed description are exemplary, but are not restrictive, of the invention.

BRIEF DESCRIPTION OF THE DRAWING

The invention is best understood from the following detailed description when read in connection with the accompanying drawing. Included in the drawing are the following figures.

Fig. 1 is a flow chart illustrating steps in a method for visualizing data arrays in accordance with an embodiment of the present invention;

Fig. 2 is a flow chart illustrating steps in a method for visualizing data arrays in accordance with an embodiment of the present invention;

Fig. 3 is a flow chart illustrating steps in a method for visualizing data provided in the form of a geometric representation;

Fig. 4 is an exemplary graphical representation of a simple dense array that is helpful in understanding an embodiment of the present invention;

Fig. 5 is an exemplary circuit schematic;

Fig. 6 is a block diagram representation of an exemplary power distribution circuit of an integrated circuit;

Fig. 7 is a more detailed circuit model for R_{ICs} and R_{ICg} of Fig. 6;

Fig. 8 shows an exemplary physical model for R_{ICs} and R_{ICg} of Fig. 7; and

Fig. 9 illustrates metalization levels and inter-level connections of Fig. 8 as sparsely connected resistive grids.

DETAILED DESCRIPTION OF THE INVENTION

5   In integrated circuit physical design systems, for example, special shapes associated with the integrated physical circuit layout are described by a syntax of a language such as, for example, Graphics Language 1 (GL1) or Graphic Design Language (GDS). These languages provide

10   mechanisms to describe three-dimensional space, orientation, and parametric information such as power service terminal (PST), logic service terminal, and IC package to IC interconnections. The shapes described by languages such as GL1, GDS, or the like are placed on a grid that represents

15   the physical area of an integrated circuit (a chip). The geometric description language may then be used to build a set of photolithographic masks. Each mask represents a different step in the manufacture of an integrated circuit. Different geometric characteristics of the lithographic

20   masks represent transistors, wires, insulation, or the like, of the integrated circuit. The integrated circuit may be manufactured on a silicon substrate with insulated interconnects (wires). The geometric shapes involved in an integrated circuit are typically on a microscopic scale.

25   Such a manufacturing process is a planar, or layered, process in which transistors may occupy the lower levels and the interconnects and insulation occupy the remaining higher levels.

        A physical design system such as, for example, the

30   Cadence™ system may graphically display or print out information, such as a grid including geometric shapes,

coded in a geometric description language such as GL1. Physical design software systems typically have large memory capacity to accommodate the shapes involved in the design of an integrated circuit. A physical design system may accommodate designs having millions of shapes, such as the shapes involved in an integrated circuit which are typically on a microscopic scale. Hence, a physical design system may graphically illustrate data arrays with millions of data variables.

Fig. 1 is a flow chart illustrating steps in a method for visualizing data arrays in accordance with an embodiment of the present invention. In step **102**, a multi-dimensional grid is generated. The position of data values in an array, for example, the rows, columns, and planes, may be used to generate the grid. In other words, the grid may be treated as a template for a numerical array, or the grid may act as a reference in a similar manner to a coordinate system. The grid may subsequently be used as a reference for the placement of geometric shapes.

In step **104**, arbitrary geometric shapes are associated with the data values in the array. That is, each entry or data value is identified with a geometric shape such as, for example, a line, a circle, a rectangle, a triangle, or a dodecahedron. Numerical properties of the data values such as, for example, magnitude and sign as well as the type of data values, for example, real or complex may be used to determine the choice of geometric shape. Numerical properties may be used to determine the sort of geometric shape identified with a data value as well as the relative size and appearance of the shape. For example, a positive, real number may be represented by a solid square;

a negative, real number may be represented by an open
square. Thus, a graphical representation of the dense array

$$\begin{bmatrix} 1 & -1 & -1 \\ -1 & 1 & -1 \\ -1 & -1 & 1 \end{bmatrix}$$

may be constructed as illustrated in Fig. 4.

5   For example, consider a system that uses graphics
capabilities, such as an integrated circuit physical design
system. In such a physical design system, geometric shapes
may be used to represent circuit components including
transistors, interconnects (wires), and insulation. Such
10   circuit components are represented by data values detailing
various technical specifications of the components. For
example, the dimensions of a transistor length or width may
be specified in micrometers (e.g., 0.6×10^{-6} meters) and the
electrical resistance of a conductor may be specified in
15   ohms (e.g., $1.5 \times 10^{-3} \Omega$).

          In step **106**, the geometric shapes associated with
the data values are placed on the grid. The grid may be
multi-dimensional so as to correspond to a multi-dimensional
array. The positioning of a geometric shape on the grid is
20   related to the index of a data value entry of the array.

          In step **108**, the information contained in the
grid, including the geometric shapes, is reported to a user.
It is preferable to report the information to a user on a
computer display or in the form of a printout.

The present invention may take advantage of the capability of a physical design software system to graphically display numerical data arrays. As detailed in the steps shown in Fig. 1, numerical and structural properties of data arrays may be represented in a form that is recognized by a physical design system. The data array displayed, for example, in a printout makes it possible to visualize properties of a data array.

If a data array is sparse, for example, then by visualizing the data array it may be possible to observe certain patterns. Sparsity patterns may lead to the choosing of suitable numerical methods, or reordering schemes with which to treat the data array. Sparsity patterns may also provide insight into the possibility of parallel processing of the data array. An integrated circuit visualization of the array may be used to determine circuit properties such as, for example, points of high current or points of low voltage. If the data values in the data array represent numerical data that is part of a larger computational process, then visualizing the data array may help to detect computationally intensive portions of the process.

Fig. 2 is a flow chart illustrating steps in a method for visualizing data arrays in accordance with an embodiment of the present invention. In the same way as in step **102** of Fig. 1, a grid is generated in step **202**. In step **204**, numerical attributes associated with data values of the data array are identified. Numerical attributes associated with data values may include the sign of a data value and the range of magnitude of a data value. In step **206**, visual attributes are associated with numerical attributes identified in step **204**. Visual attributes may

include, for example, color, hue, brightness, and saturation. Visual attributes may be used to highlight numerical properties of the data values of the data array. For example, the range and distribution of the numerical magnitude of data values may be highlighted by a variety of colors and changes in brightness.

In step **208**, geometric shapes having the proper visual attributes are associated with the data values in the array. In other words, each data value, having a numerical attribute, is associated with a geometric shape, having a visual attribute, through the association performed in step **206**. For example, a geometric shape associated with a data value with a magnitude belonging to a particular range of magnitudes has the color associated with that range of magnitudes.

In step **210**, similarly to step **106** of Fig. 1, the geometric shapes associated with the data values are placed on the grid. In step **212**, which is the same as step **108** of Fig. 1, the information contained in the grid including the geometric shapes is reported to a user. It is preferable to report the information to a user on a computer display or in the form of a printout.

In the foregoing, a method is described for visualizing data arrays provided in the form of data values. The data are associated with geometric shapes placed on a grid. It is also possible, in accordance with another embodiment of the present invention, to visualize data provided in the form of a geometric representation. Fig. 3 is a flow chart illustrating steps in a method for visualizing data provided in the form of a geometric representation. A graphic representation may be coded, for

example, in a geometric description language such as GL1, GDS, or the like. In step **302,** data values, such as numerical data values, are extracted from a geometric representation. Consider the case in which the geometric representation is an integrated circuit layout. In this case, numerical data values are obtained by extracting power buses and network resistance from the integrated circuit layout. The numerical data values thus obtained may then be organized in a data array such as a matrix.

In step **304,** a graphic representation of the data values is generated. Such a graphic representation may be, for example, a graphic representation of a sparse matrix. If the graphic representation is an integrated circuit layout, such a sparse matrix may be a conductance matrix obtained, for example, as part of quiescent drain current analysis. A graphic representation of a sparse matrix may be, for example, a grid corresponding to rows and columns of a matrix in which a colored dot is placed on the grid for each non-zero entry in the matrix.

In step **306,** the graphic representation is displayed to a user. A physical design software system such as the Cadence™ system may be used to display a graphic representation, such as a representation of a sparse matrix. A physical design software system may be used to print a colored graphic representation of a sparse matrix.

The use of a physical design software system for the implementation of the present invention is advantageous because such systems can handle large volumes of data. It may in fact be the case that, for some applications, the amount of memory required to store a graphic representation, coded in a geometric description language such as GL1, is

larger than the amount of memory required to store the extracted data values.

EXAMPLE

The following example is included to more clearly
5   demonstrate the overall nature of the invention: a method for visualization of numerical matrices. The entries of the matrices may include multi-dimensional, linear, and/or non-linear numerical expressions. This example is exemplary, not restrictive, of the invention.

10   Matrices are useful constructs both in theoretical and applied mathematical analysis. Specifically, in the field of dynamical systems matrices are useful in the course of both "steady-state" (time independent) and "dynamic" (time dependent) analysis. Both steady-state and dynamic
15   analyses may be performed in relation to dynamic systems arising in the fields of electrical, hydraulic, thermal, and mechanical engineering.

Kirchoff's Current Law (KCL) is a specific example from circuit analysis. KCL is a conservative law which
20   states that the sum of the currents "entering" and "exiting" a node in an electrical network equals zero. A node is defined as the junction of two or more electrical components. Fig. 5 is an exemplary circuit schematic illustrating five such nodes, labeled 0 through 4,
25   connecting between resistors labeled R0, R1, R2, R3, R4, R5, R6, and R7. Table 1 shows a "net list" associated with the circuit of Fig. 5. The "net list" is a tabular representation of the circuit or electrical network of Fig. 5. Table 1 provides all of the information included in the
30   circuit diagram of Fig. 5.

TABLE 1
"Net List"

MODEL NAME	FROM NODE	TO NODE	VALUE
R0	0	1	1
R1	0	3	2
R2	0	2	3
R3	1	2	4
R4	3	2	5
R5	1	4	6
R6	2	4	7
R7	3	4	8
I_s	0	4	I

5

Another equivalent representation of the circuit
of Fig. 5 may be obtained by applying KCL. In matrix form
the representation of the circuit of Fig. 5 is denoted by
the following equation:

$$G * v = \begin{bmatrix} 6 & -1 & -3 & -2 & 0 \\ -1 & 11 & -4 & 0 & -6 \\ -3 & -4 & 19 & -5 & -7 \\ -2 & 0 & -5 & 15 & -8 \\ 0 & -6 & -7 & -8 & 21 \end{bmatrix} * \begin{bmatrix} v_0 \\ v_1 \\ v_2 \\ v_3 \\ v_4 \end{bmatrix} = i = \begin{bmatrix} I_s \\ 0 \\ 0 \\ 0 \\ -I_s \end{bmatrix} ,$$

10

where G is a matrix that represents the conductance of
resistive components R0 through R7 in the circuit, v is a
vector of node voltages, and i is a vector of branch
currents. Thus, the dimension, or "size", of G, v, and i

15   each depends on the number of nodes in the circuit. In
other words, the greater the number of nodes, the larger the
"size" of matrix G and vectors v and i.

A circuit that results in a relatively large
conductance matrix G is the power distribution circuit of an

integrated circuit (IC). Fig. 6 is a block diagram
representation of such a circuit. The circuit of Fig. 6
includes: an external power supply with an "earth"
reference, a source voltage, and a ground voltage; a

5   resistor R_{PKG}, representing the resistance of the IC package;
a resistor R_{IC}, representing the resistance of the IC power
distribution metalization layers; and IC transistors. Fig.
6 illustrates that the voltage delivered to the IC
transistors is "divided" by R_{PKG} and R_{IC}, where V_{ps} is lowered

10   by the voltage drop across R_{PKG_S} and R_{IC_S}, as given by the
equation:

$$V_{PFET_S} = V_{ps_S} - V_{PKG_S} - V_{IC_S} ,$$

and V_{ps_G} is raised by the voltage drop across R_{PKGG} and R_{ICG},
as given by the equation:

15   $$V_{NFET_G} = V_{ps_G} + V_{PKG_G} + V_{IC_G} .$$

Fig. 7 shows a more detailed circuit model for R_{IC_S}
and R_{IC_G}, where each "level" of IC metalization is modeled as
a separate resistor. A contemporary IC may have ten levels
to connect V_{ps_S} to V_{PFET_S}, and an additional ten levels to

20   connect V_{NFET_G} to V_{ps_G}.

Fig. 8 shows the corresponding physical model for
R_{IC_S} and R_{IC_G} of Fig. 7, where a metalization level is shown
as a rectangle, and an inter-level connection or "via" is
represented as a square.

25   Fig. 9 illustrates the levels and vias of Fig. 8
as sparsely connected resistive grids. A contemporary IC
may have approximately five million resistors in each
resistive block. Therefore, the resulting conductance

matrix G may be of on the order of 3.5 million X 3.5
million. Such a matrix is very large.

    As applied to this exemplary embodiment, the
present invention provides a way to organize the rows and
columns of conductance matrix G. Matrix G may be organized
so that the entries of matrix G correspond to the physical
position of nodes in the circuit. The physical position of
nodes in the circuit is shown, for example, in Fig. 9. The
following matrix-vector equation G*v=i corresponds to such a
reorganization of matrix G for the circuit diagrams of Figs.
7 and 8.

$$
\begin{bmatrix}
1 & -1 \\
-1 & 2 & -1 \\
 & -1 & 2 & -1 \\
 & & -1 & 2 & -1 \\
 & & & -1 & 2 & -1 \\
 & & & & -1 & 2 & -1 \\
 & & & & & -1 & 2 & -1 \\
 & & & & & & -1 & 2 & -1 \\
 & & & & & & & -1 & 2 & -1 \\
 & & & & & & & & -1 & 2 & -1 \\
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 & & & & & & & & & & & & & & & & -1 & 2 & -1 \\
 & & & & & & & & & & & & & & & & & -1 & 2 & -1 \\
 & & & & & & & & & & & & & & & & & & -1 & 2 & -1 \\
 & & & & & & & & & & & & & & & & & & & -1 & 2 & -1 \\
 & & & & & & & & & & & & & & & & & & & & -1 & 1
\end{bmatrix}
*
\begin{bmatrix}
i_{PKG_s} \\
i_{LV_s} \\
i_{LM_s} \\
i_{V4_s} \\
i_{M4_s} \\
i_{V3_s} \\
i_{M3_s} \\
i_{V2_s} \\
i_{M2_s} \\
i_{V1_s} \\
i_{M1_s} \\
i_{M1_G} \\
i_{V1_G} \\
i_{M2_G} \\
i_{V2_G} \\
i_{M3_G} \\
i_{V3_G} \\
i_{M4_G} \\
i_{V4_G} \\
i_{LM_G} \\
i_{LV_G} \\
i_{PKG_G}
\end{bmatrix}
=
\begin{bmatrix}
v_{PKG_s} \\
v_{LV_s} \\
v_{LM_s} \\
v_{V4_s} \\
v_{M4_s} \\
v_{V3_s} \\
v_{M3_s} \\
v_{V2_s} \\
v_{M2_s} \\
v_{V1_s} \\
v_{M1_s} \\
v_{M1_G} \\
v_{V1_G} \\
v_{M2_G} \\
v_{V2_G} \\
v_{M3_G} \\
v_{V3_G} \\
v_{M4_G} \\
v_{V4_G} \\
v_{LM_G} \\
v_{LV_G} \\
v_{PKG_G}
\end{bmatrix}
$$

where all zero entries have been left blank, all resistive
values have been set to one ohm, and the corresponding
resistors are connected serially. Hence, conductance matrix

G is organized such that adjacent resistors in the circuit appear as adjacent entries in matrix G.

Although illustrated and described herein with reference to certain specific embodiments, the present invention is nevertheless not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the spirit of the invention. The present invention can further be embodied in the form of computer-implemented processes and apparatus for practicing such processes, for example, and can be embodied in the form of computer program code embodied in tangible media, such as floppy diskettes, fixed (hard) drives, CD ROM's, magnetic tape, fixed/integrated circuit devices, or any other computer-readable storage medium, such that when the computer program code is loaded into and executed by a computer, the computer becomes an apparatus for practicing the invention.

What is Claimed:

1. A method for visualizing data arrays provided
in the form of a plurality of data values, said method
comprising the steps of:

generating a grid based on the plurality of data
values;

associating each data value of the plurality of
data values with one of a plurality of geometric shapes
according to a predetermined set of rules;

placing said one of the plurality of geometric
shapes associated with each data value of the plurality of
data values on the grid; and

displaying visual and geometric information placed
on the grid to a user in graphical form.

2. A method for visualizing data arrays provided
in the form of a plurality of data values, said method
comprising the steps of:

generating a grid based on the plurality of data
values;

identifying one of a plurality of numerical
attributes associated with each data value of the plurality
of data values;

associating each numerical attribute with one of a
plurality of visual attributes;

11   associating each data value of the plurality of
12 data values with one of a plurality of geometric shapes each
13 having one of the plurality of visual attributes, which is
14 consistent with the data value, according to a predetermined
15 set of rules;

16   placing said one of the plurality of geometric
17 shapes associated with each data value of the plurality of
18 data values on the grid; and

19   displaying visual and geometric information placed
20 on the grid to a user in graphical form.

1   3.   A method for visualizing data provided in the
2 form of a geometric representation, said method comprising
3 the steps of:

4   extracting a plurality of data values from the
5 geometric representation;

6   generating a graphic representation of the
7 plurality of data values; and

8   displaying the graphic representation to a user.

1   4.   The method according to claim 3, wherein the
2 graphic representation of the plurality of data values is
3 the graphic representation of a conductance matrix.

1   5.   An article of manufacture comprising a
2 computer usable medium having computer readable program code
3 means embodied therein for visualizing data arrays provided
4 in the form of a plurality of data values, the computer
5 readable program code means in said article of manufacture

6   comprising computer readable program code means for causing
7   a computer to effect:

8   generating a grid based on the plurality of data
9   values;

10   associating each data value of the plurality of
11   data values with one of a plurality of geometric shapes
12   according to a predetermined set of rules;

13   placing said one of the plurality of geometric
14   shapes associated with each data value of the plurality of
15   data values on the grid; and

16   displaying visual and geometric information placed
17   on the grid to a user in graphical form.

1   6.   An article of manufacture comprising a
2   computer usable medium having computer readable program code
3   means embodied therein for visualizing data arrays provided
4   in the form of a plurality of data values, the computer
5   readable program code means in said article of manufacture
6   comprising computer readable program code means for causing
7   a computer to effect:

8   generating a grid based on the plurality of data
9   values;

10   identifying one of a plurality of numerical
11   attributes associated with each data value of the plurality
12   of data values;

13   associating each numerical attribute with one of a
14   plurality of visual attributes;

15   associating each data value of the plurality of
16 data values with one of a plurality of geometric shapes each
17 having one of the plurality of visual attributes, which is
18 consistent with the data value, according to a predetermined
19 set of rules;

20   placing said one of the plurality of geometric
21 shapes associated with each data value of the plurality of
22 data values on the grid; and

23   displaying visual and geometric information placed
24 on the grid to a user in graphical form.

1   7.   An article of manufacture comprising a
2 computer usable medium having computer readable program code
3 means embodied therein for visualizing data provided in the
4 form of a geometric representation, the computer readable
5 program code means in said article of manufacture comprising
6 computer readable program code means for causing a computer
7 to effect:

8   extracting a plurality of data values from the
9 geometric representation;

10   generating a graphic representation of the
11 plurality of data values; and

12   displaying the graphic representation to a user.

1   8.   The article of manufacture according to claim
2 7, wherein the graphic representation of the plurality of
3 data values is the graphic representation of a conductance
4 matrix.

1   9.   A computer program product comprising a
2 computer usable medium having computer readable program code
3 means embodied therein for causing visualization of data
4 arrays provided in the form of a plurality of data values,
5 the computer readable program code means in said computer
6 program product comprising computer readable program code
7 means for causing a computer to effect:

8   generating a grid based on the plurality of data
9 values;

10   associating each data value of the plurality of
11 data values with one of a plurality of geometric shapes
12 according to a predetermined set of rules;

13   placing said one of the plurality of geometric
14 shapes associated with each data value of the plurality of
15 data values on the grid; and

16   displaying visual and geometric information placed
17 on the grid to a user in graphical form.

1   10. A computer program product comprising a
2 computer usable medium having computer readable program code
3 means embodied therein for causing visualization of data
4 arrays provided in the form of a plurality of data values,
5 the computer readable program code means in said computer
6 program product comprising computer readable program code
7 means for causing a computer to effect:

8   generating a grid based on the plurality of data
9 values;

10   identifying one of a plurality of numerical
11 attributes associated with each data value of the plurality
12 of data values;

13   associating each numerical attribute with one of a
14 plurality of visual attributes;

15   associating each data value of the plurality of
16 data values with one of a plurality of geometric shapes each
17 having one of the plurality of visual attributes, which is
18 consistent with the data value, according to a predetermined
19 set of rules;

20   placing said one of the plurality of geometric
21 shapes associated with each data value of the plurality of
22 data values on the grid; and

23   displaying visual and geometric information placed
24 on the grid to a user in graphical form.

1   11. A computer program product comprising a
2 computer usable medium having computer readable program code
3 means embodied therein for causing visualization of data
4 provided in the form of a geometric representation, the
5 computer readable program code means in said computer
6 program product comprising computer readable program code
7 means for causing a computer to effect:

8   extracting a plurality of data values from the
9 geometric representation;

10   generating a graphic representation of the
11 plurality of data values; and

12   displaying the graphic representation to a user.

1   12.   The product according to claim 11, wherein
2   the graphic representation of the plurality of data values
3   is the graphic representation of a conductance matrix.

1   13.   A storage device readable by machine,
2   tangibly embodying a program of instructions executable by
3   the machine to perform a method for visualizing data arrays
4   provided in the form of a plurality of data values, said
5   method comprising the steps of:

6   generating a grid based on the plurality of data
7   values;

8   associating each data value of the plurality of
9   data values with one of a plurality of geometric shapes
10   according to a predetermined set of rules;

11   placing said one of the plurality of geometric
12   shapes associated with each data value of the plurality of
13   data values on the grid; and

14   displaying visual and geometric information placed
15   on the grid to a user in graphical form.

1   14.   A storage device readable by a machine,
2   tangibly embodying a program of instructions executable by
3   the machine to perform a method for visualizing data arrays
4   provided in the form of a plurality of data values, said
5   method comprising the steps of:

6   generating a grid based on the plurality of data
7   values;

8   identifying one of a plurality of numerical
9 attributes associated with each data value of the plurality
10 of data values;

11   associating each numerical attribute with one of a
12 plurality of visual attributes;

13   associating each data value of the plurality of
14 data values with one of a plurality of geometric shapes each
15 having one of the plurality of visual attributes, which is
16 consistent with the data value, according to a predetermined
17 set of rules;

18   placing said one of the plurality of geometric
19 shapes associated with each data value of the plurality of
20 data values on the grid; and

21   displaying visual and geometric information placed
22 on the grid to a user in graphical form.

1   15. A storage device readable by a machine,
2 tangibly embodying a program of instructions executable by
3 the machine to perform a method for visualizing data
4 provided in the form of a geometric representation, said
5 method comprising the steps of:

6   extracting a plurality of data values from the
7 geometric representation;

8   generating a graphic representation of the
9 plurality of data values; and

10   displaying the graphic representation to a user.

1   16.   The device according to claim 15, wherein the

2 graphic representation of the plurality of data values is

3 the graphic representation of a conductance matrix.

METHOD FOR VISUALIZING DATA

ABSTRACT

A system and method for visualizing data. Data are provided either in the form of data values of a data array or in the form of a geometric representation. A data array may be, for example, a sparse matrix. A geometric representation, may be, for example, an integrated circuit layout coded in a geometric description language. Data provided in the form of data values are associated with geometric shapes placed on a grid. Information placed on the grid is then reported to a user. If data are provided in the form of a geometric representation, then data values are extracted from the geometric representation. A graphic representation is generated from the extracted data values. The graphic representation is exhibited to a user.
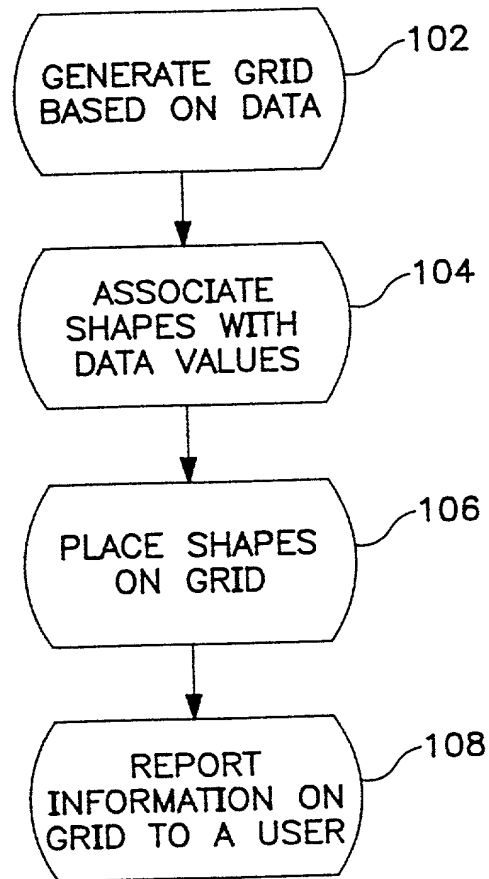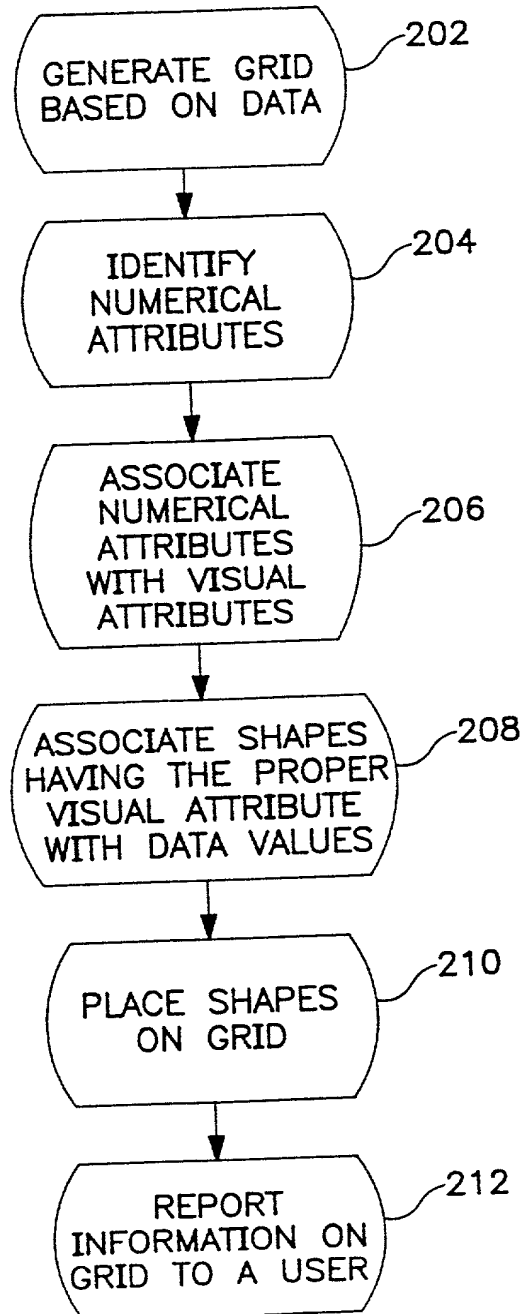
GENERATE GRID
BASED ON DATA — 102

ASSOCIATE
SHAPES WITH
DATA VALUES — 104

PLACE SHAPES
ON GRID — 106

REPORT
INFORMATION ON
GRID TO A USER — 108

FIG. 1

GENERATE GRID
BASED ON DATA ⟋202

↓

IDENTIFY
NUMERICAL
ATTRIBUTES ⟋204

↓

ASSOCIATE
NUMERICAL
ATTRIBUTES
WITH VISUAL
ATTRIBUTES ⟋206

↓

ASSOCIATE SHAPES
HAVING THE PROPER
VISUAL ATTRIBUTE
WITH DATA VALUES ⟋208

↓

PLACE SHAPES
ON GRID ⟋210

↓

REPORT
INFORMATION ON
GRID TO A USER ⟋212

FIG. 2

A GEOMETRIC REPRESENTATION OF DATA

EXTRACT
DATA
VALUES — 302

GENERATE
GRAPHIC
REPRESENTATION — 304

EXHIBIT
GRAPHIC
REPRESENTATION
TO A USER — 306
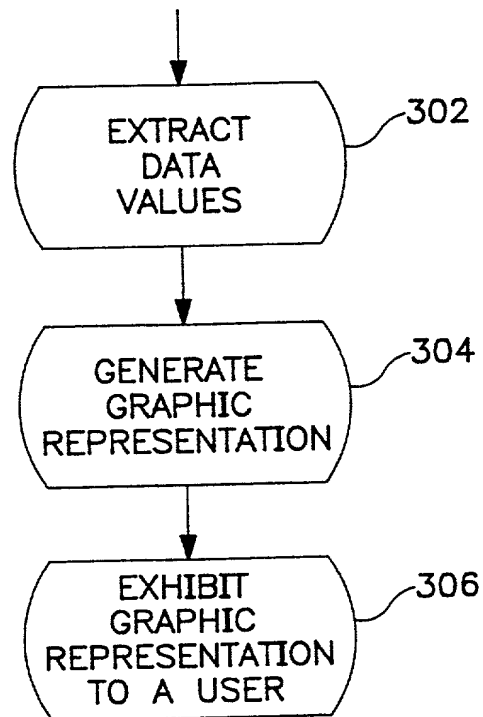
FIG. 3

$$\begin{bmatrix} 1 & -1 & -1 \\ -1 & 1 & -1 \\ -1 & -1 & 1 \end{bmatrix} =$$
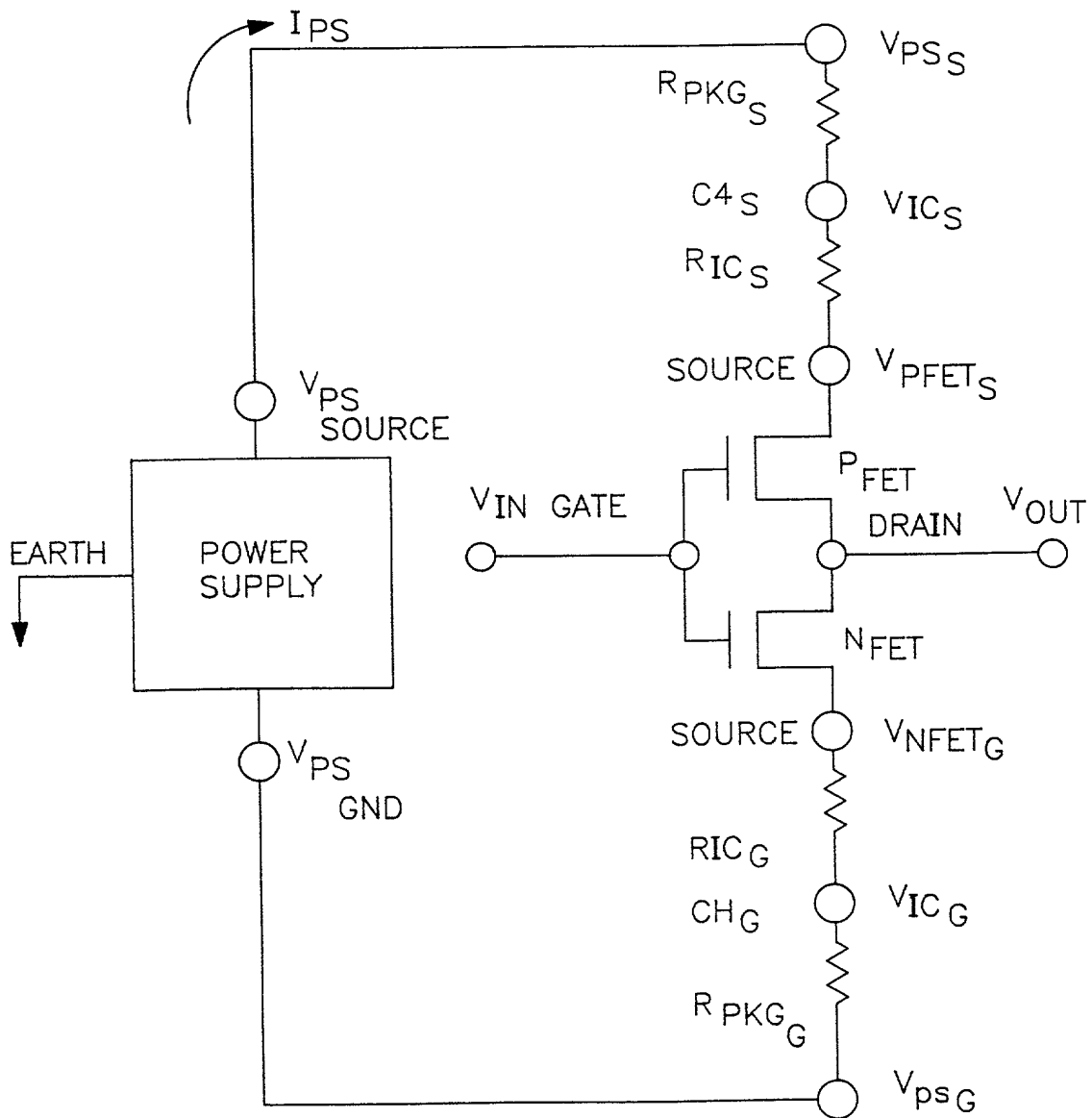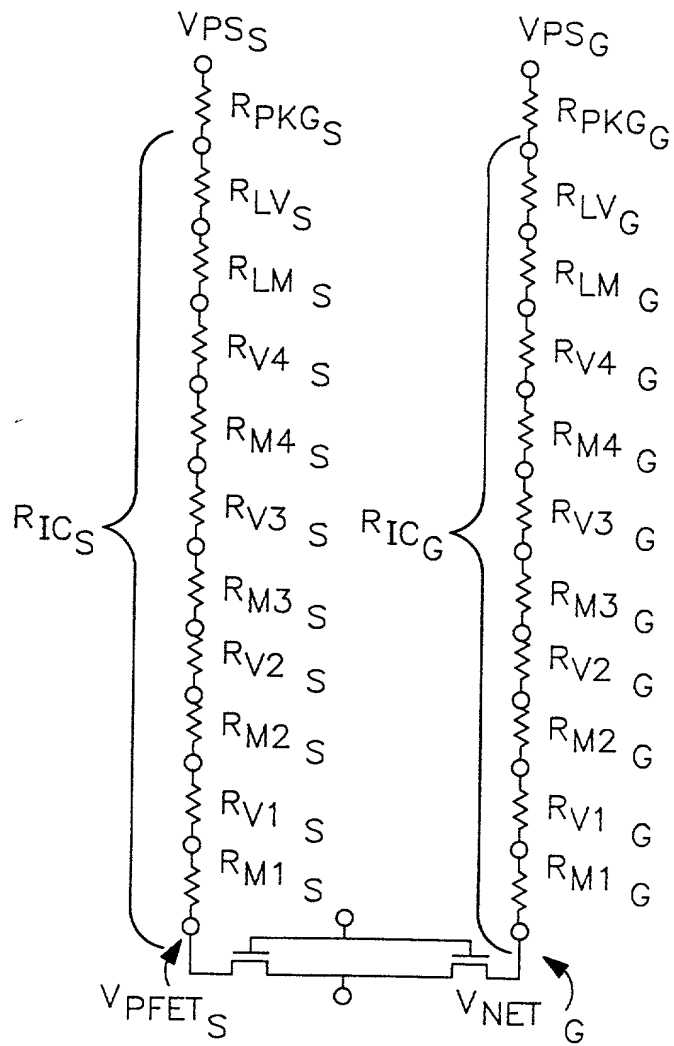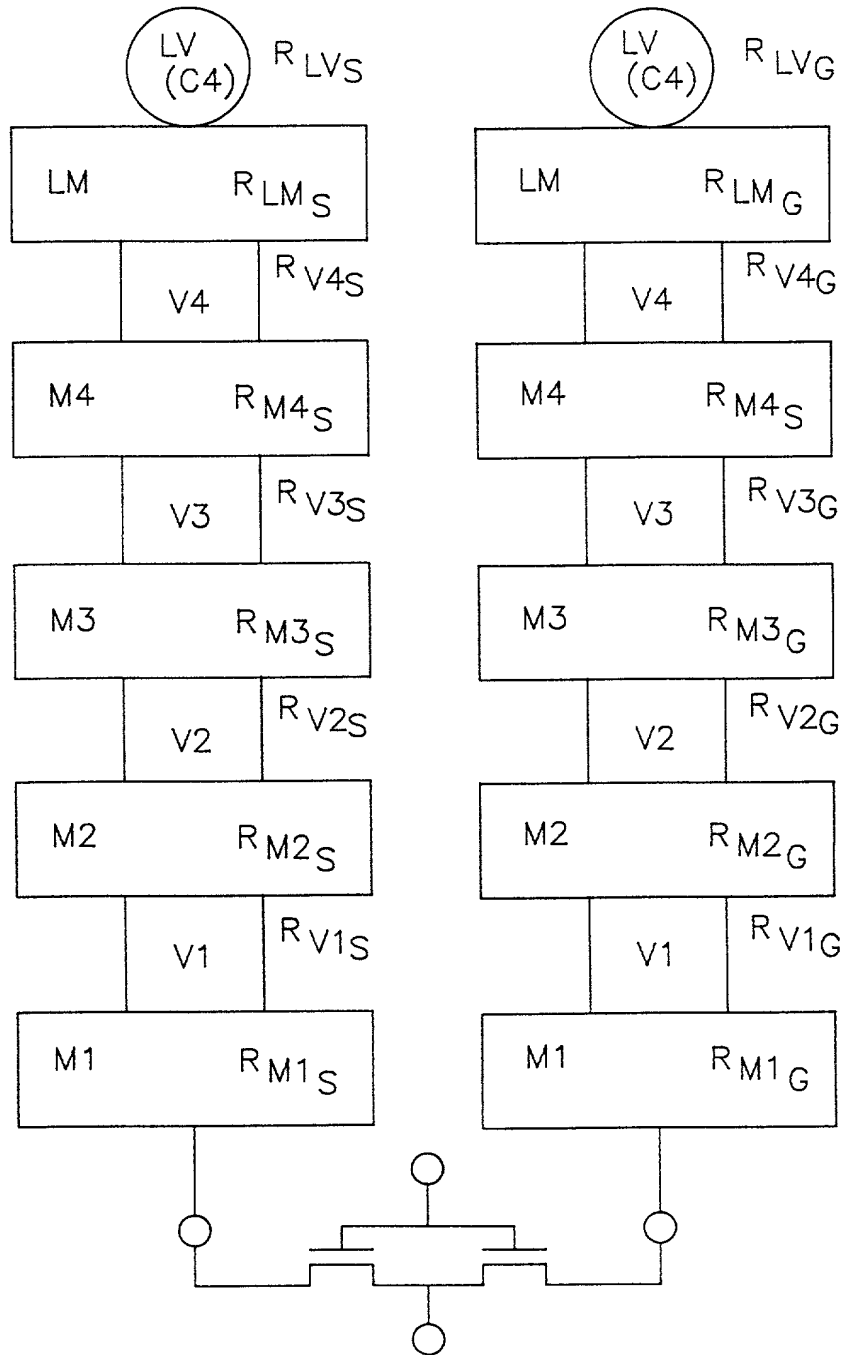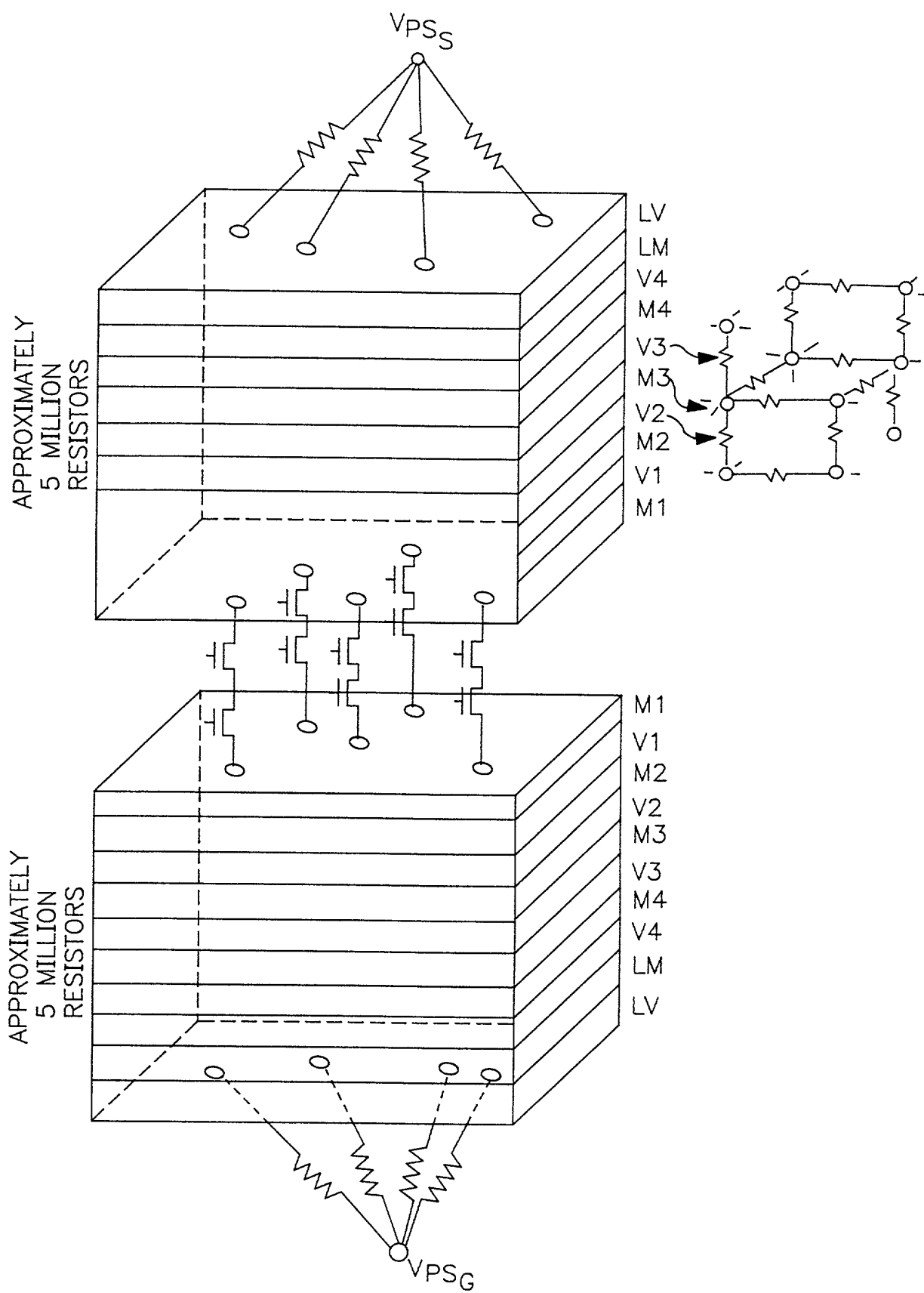

FIG. 4
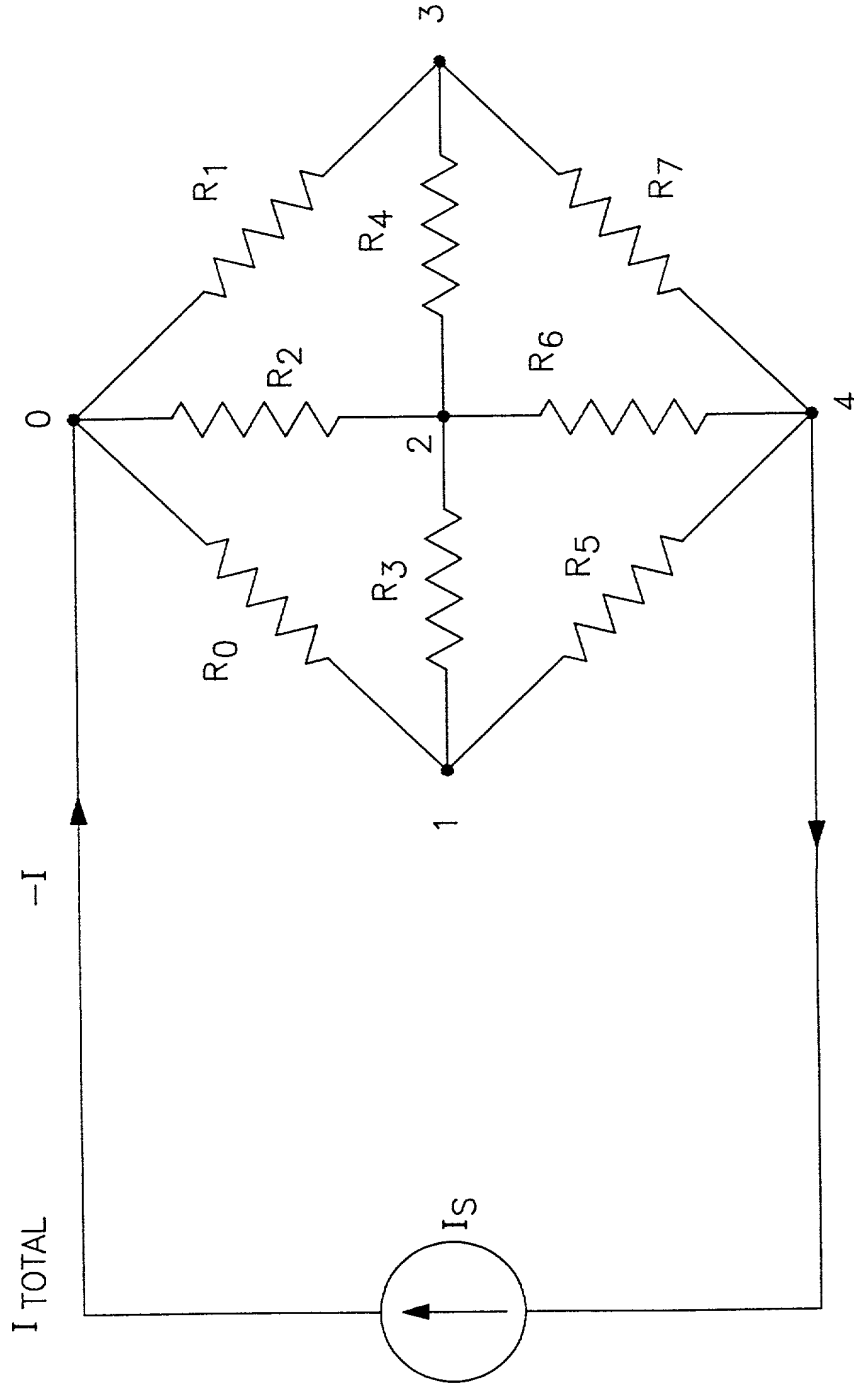
FIG. 5

FIG. 6

FIG. 7

FIG. 8

FIG. 9

Declaration and Power of Attorney For Patent Application
English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled METHOD FOR VISUALIZING DATA, the specification of which is attached hereto unless the following box is checked:

☐ was filed on ___ as
   United States Application Number or PCT International Application Number ___
   and was amended on ___ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)   Priority Not Claimed

___   ___   ___
(Number)   (Country)   (Day/Month/Year Filed)   ☐

___   ___   ___
(Number)   (Country)   (Day/Month/Year Filed)   ☐

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below.

___   ___
(Application Number)   (Filing Date)

___   ___
(Application Number)   (Filing Date)

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

_____   _____   _____
(Application Number)   (Filing Date)   (Status - patented, pending, abandoned)

_____   _____   _____
(Application Number)   (Filing Date)   (Status - patented, pending, abandoned)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

Paul F. Prestia	Reg. No. 23,031	Jacques L. Etkowicz	Reg. No. 41,738	Mark F. Chadurjian	Reg. No. 30,739
Allan Ratner	Reg No. 19,717	Eric A. Dichter	Reg. No. 41,708	Dale M. Crockatt	Reg. No. 35,109
Andrew L. Ney	Reg. No. 20,300	Rocco L. Adornato	Reg. No. 40,480	Richard M. Kotulak	Reg. No. 27,712
Kenneth N. Nigon	Reg. No. 31,549	Mark J. Marcelli	Reg. No. 36,593	James M. Leas	Reg No. 34,372
Kevin R. Casey	Reg No 32,117	Joshua L. Cohen	Reg. No. 38,040	William D Sabo	Reg. No 27,465
Benjamin E Leace	Reg No 33,412	Christopher J. Dervishian	Reg. No 42,480	Eugene I. Shkurko	Reg. No. 36,678
James C. Simmons	Reg. No. 24,842	Jack J. Jankovitz	Reg. No. 42,690	Robert A. Walsh	Reg. No. 26,516
Lawrence E. Ashery	Reg. No. 34,515	Costas S. Krikelis	Reg. No. 28,028	Howard J. Walter, Jr.	Reg. No. 24,832
Christopher R. Lewis	Reg. No. 36,201	William P. Hauser	Reg. No. 26,277	Christopher A. Hughes	Reg. No. 26,914
Robert L. Andersen	Reg. No. 25,771	Bruce M. Monroe	Reg. No. 33,602	John E. Hoel	Reg. No. 26,279
Daniel N. Calder	Reg. No. 27,424	Rex A. Donnelly, IV	Reg. No. 41,712	Edward A. Pennington	Reg. No. 32,588
Louis W. Beardell, Jr.	Reg. No. 40,506	Paul D. Golian	Reg. No. P42,591	Joseph C. Redmond, Jr.	Reg. No. 18,753

Address all correspondence to: Kevin R. Casey
  Ratner & Prestia, Suite 301, One Westlakes, Berwyn, P.O. Box 980, Valley Forge, PA 19482-0980
Address all telephone calls to: Kevin R. Casey at (610) 407-0700.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor (given name, family name) **Cassondra L. Crotty**

Inventor's signature _____   Date _____
Residence 52 Hitchcock Lane, Avon, Connecticut 06001
Citizenship USA
Post Office Address 52 Hitchcock Lane
                     Avon, CT 06001

Full name of second joint inventor, if any (given name, family name) **Daria R. Dooling**

Second Inventor's signature ___*Daria R Dooling*_____   Date 12/16/98
Residence 307 Pond Road, Huntington, Vermont 05462
Citizenship USA
Post Office Address 307 Pond Road
                     Huntington, VT 05462

☒ Additional inventors are being named on separately numbered sheets attached hereto.

Full name of third joint inventor, if any (given name, family name) **David E. Moran**

Third inventor's signature _David E. Moran_   Date _DEC 16ᵀᴴ, 1998_

Residence 21 Deerfield Road, South Burlington, Vermont 05403

Citizenship USA

Post Office Address 21 Deerfield Road

                           South Burlington, VT 05403

Full name of fourth joint inventor, if any (given name, family name) **Ralph J. Williams**

Fourth inventor's signature _Ralph J. Williams_   Date _12/16/1998_

Residence 9 Hanley Lane, Essex Junction, Vermont 05452

Citizenship USA

Post Office Address 9 Hanley Lane

                           Esse Junction, VT 05452

(Application Number)	(Filing Date)	(Status - patented, pending, abandoned)
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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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Full name of sole or first inventor (given name, family name) **Cassondra L. Crotty**

Inventor's signature _Cassondra L Crotty_   Date _12/18/98_
Residence **52 Hitchcock Lane, Avon, Connecticut 06001**
Citizenship **USA**
Post Office Address **52 Hitchcock Lane**
                   Avon, CT 06001

Full name of second joint inventor, if any (given name, family name) **Daria R. Dooling**

Second Inventor's signature _Daria R Dooling_   Date _12/16/98_
Residence **307 Pond Road, Huntington, Vermont 05462**
Citizenship **USA**
Post Office Address **307 Pond Road**
                   Huntington, VT 05462

☒ Additional inventors are being named on separately numbered sheets attached hereto.

Full name of third joint inventor, if any (given name, family name) <u>David E. Moran</u>

Third inventor's signature _David E. Moran_ Date DEC 16ᵗᴴ, 1998

Residence <u>21 Deerfield Road, South Burlington, Vermont 05403</u>

Citizenship <u>USA</u>

Post Office Address <u>21 Deerfield Road</u>

<u>South Burlington, VT 05403</u>

Full name of fourth joint inventor, if any (given name, family name) <u>Ralph J. Williams</u>

Fourth inventor's signature _Ralph J Williams_ Date _12/16/1998_

Residence <u>9 Hanley Lane, Essex Junction, Vermont 05452</u>

Citizenship <u>USA</u>

Post Office Address <u>9 Hanley Lane</u>

<u>Esse Junction, VT 05452</u>